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THE VELIGER

A New Species of Eastern Pacific *Fissidentalium* (Mollusca: Scaphopoda) with a Symbiotic Sea Anemone

by

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Abstract. *Fissidentalium* ***actiniophorum*** sp. nov. is described morphometrically from specimens collected from deep water off California. The nearest geographical members of *Fissidentalium* are *Fissidentalium megathyris* and *Fissidentalium erosum*. *Fissidentalium* ***actiniophorum*** is distinguished from these species primarily on the basis of shell and soft-body-part proportions. Five shell and five soft-part measurements were taken. From these an additional eight shell and four soft-part factors or indices were derived for a total of 22 factors or indices. *Fissidentalium* ***actiniophorum*** differed statistically from both *F. megathyris* and *F. erosum* in all shell measurements, all derived shell factors, and most soft-part measurements. It differed from either *F. megathyris* or *F. erosum* in one of the two ratios of the gonadal length to the total visceral length. It did not differ from either species in the ratio of the gut lobe length to the total visceral length, or in some of the ratios of gonadal length to total visceral length.

INTRODUCTION

The Pulse Project of Scripps Institution has been collecting a large species of undescribed scaphopod since about 1992 off southern California from depths of about 4100 m. Most specimens of this scaphopod carried a sea anemone on the concave functionally dorsal shell surface (Figure 1). The sea anemone was also undescribed. Sea anemone and scaphopod relationships of this nature have been occasionally noted before (Shimek & Moreno 1996; Scarabino, personal communication); however, in the present case, most of the scaphopod shells from living animals carried a sea anemone. No shells from dead scaphopods had sea anemones on them, although most showed anemone scars.

The sea anemones may be the same species found on some *Fissidentalium megathyris* (Dall, 1890) shells collected offshore of central California (Shimek & Moreno, 1996). The scaphopod, distinctly different from any other *Fissidentalium,* is described here. The sea anemone is being described separately (A. Wakefield Pagels, 1996, personal communication).

MATERIALS AND METHODS

Specimens examined for both descriptive and comparative purposes came from samples collected at depths varying from 4100 m to 4134 m in a rectangle bounded by 34.20°N in the south, 34.78°N in the north, 122.97°W in the east, and 123.23°W in the west (Table 1). This is station M of the Pulse Project conducted by Dr. Ken Smith, Scripps Institution of Oceanography. In the subsequent enumeration of specimen listing the collection data, the first digit of a three digit number or the first two digits of a four digit number represent the cruise when the specimens were collected. The last two digits of these numbers indicate the location within station M.

The new species was compared to *F. megathyris* and *F. erosum* Shimek & Moreno 1996, using the electronically stored supplemental data available by anonymous FTP (Shimek & Moreno, 1996). Those data were generated from specimens of *F. megathyris* and *F. erosum*. The *F. megathyris* were originally loaned from the California Academy of Sciences, San Francisco (CAS), and the National Museum of Natural History, Washington (USNM) (Shimek & Moreno, 1996). Specimens of *F. erosum* utilized for comparison are in the collections of the Los Angeles County Museum of Natural History (LACM); USNM; The British Natural History Museum (BMNH); and the collections of Dr. Guillermo Moreno and the author (Shimek & Moreno, 1996). Type specimens designated in this paper were deposited in the LACM, USNM, and the BMNH.

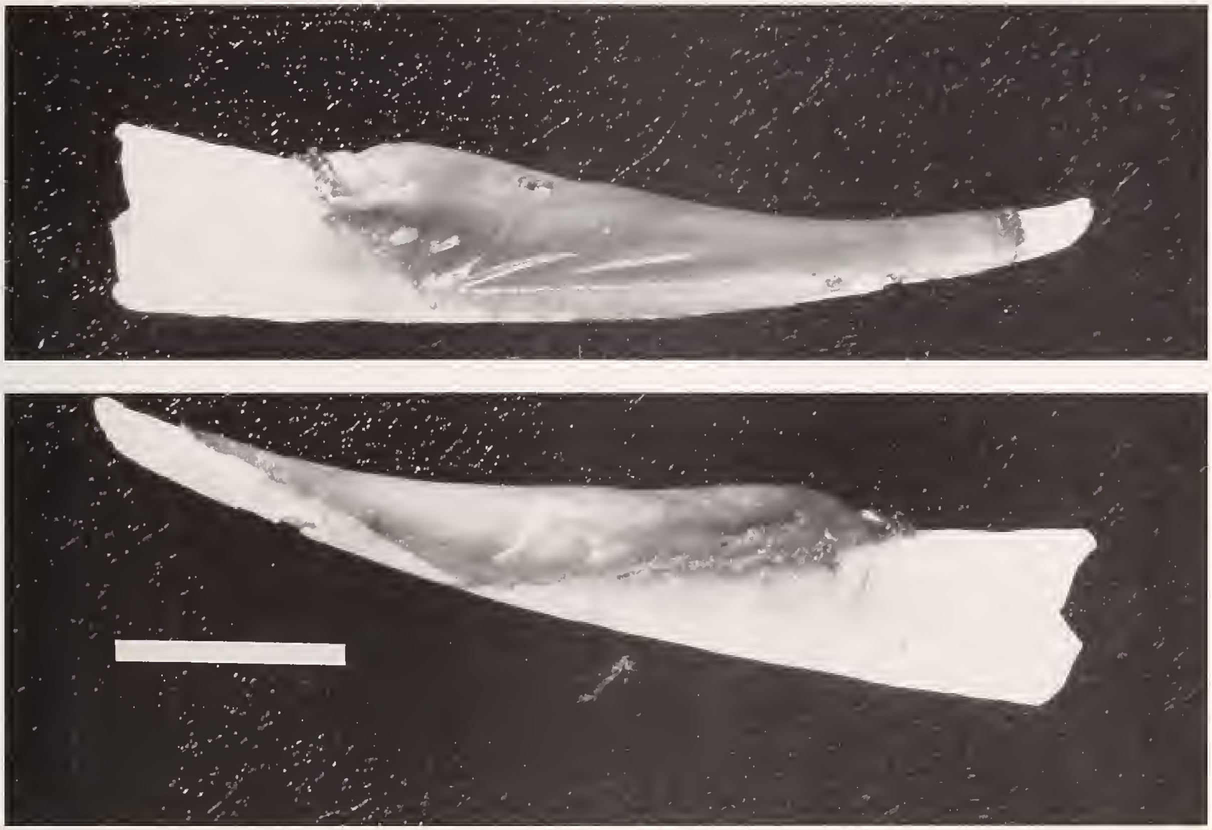

Figure 1

*F. **actiniophorum*** Shimek, sp. nov. with a sea anemone attached. Scale bar is 10 mm. This illustration was exposed to indicate the relationship between the anthozoan and the scaphopod, and resulted in loss of scaphopod shell detail. See Figures 2 and 3.

Shell Measurements and Morphometrics

For the shell description, I used an approach of quantitative shell morphometric analyses based on the mathematical properties of shell shape (Raup, 1966). Shell measurements were made following Shimek (1989), as modified by Shimek & Moreno (1996: fig. 1). The morphometric analyses ideally require "perfect" undamaged shells. Many of the adult shells from the Pulse collections were in very good condition and could be used without hesitation for this work. Nevertheless, to increase sample sizes, I occasionally found it necessary to examine and measure shells with minor fractures, apertural lip breaks, and apical fractures. In these cases, the actual shell measurements were reported and no attempt was made to estimate "perfect" conditions. Such shells were more common in the comparative specimens of *F. megathyris* and *F. erosum.* I tried to be as conservative as possible in the use of these shells, but their use undoubtedly increased variance in the analyses. For detailed derivations of the indices and measurements, see Shimek (1989).

The complete array of shell measurements was not taken

Table 1

Fissidentalium ***actiniophorum*** specimens examined.

Number of specimens	Degrees North latitude	Degrees West longitude	Date collected	Station number
8	34.73	123.13	February 21, 1992	1108M
1	34.78	123.07	February 26, 1992	1121M
13	34.62	123.12	June 26, 1992	1206M
11	34.68	123.05	July 25, 1992	1219M
12	34.63	123.02	August 22, 1992	1406M
7	34.60	123.13	October 17, 1992	1506M
22	34.72	123.07	October 30, 1992	1516M
11	34.75	123.03	February 24, 1993	1625M
9	34.72	123.10	July 19, 1993	1716M
5	34.73	123.20	November 4, 1993	1809M
4	34.20	123.13	November 7, 1993	1820M
2	34.68	123.08	February 5, 1994	1906M
5	34.68	123.18	February 10, 1994	1916M
20	34.65	122.97	June 17, 1994	2017M
11	34.67	123.18	September 22, 1994	2231M
14	34.70	123.23	October 22, 1994	2304M

on some specimens because of the presence of the sea anemone in the anatomically anterior or functionally dorsal, concave, curved region of the shell. The anemone was left in place on some specimens to assist in the description of that species. Additionally, if the measurements were made from dead shells, then soft-body-part measurements were impossible to obtain.

The comparative specimens of *F. megathyris* came from numerous localities. *Fissidentalium megathyris* was described from specimens collected near the Galapagos Islands. Shimek & Moreno (1996) used a discriminant analysis classification for the factor of collection location to verify that the Californian *F. megathyris* specimens were indistinguishable from the Galapagos type specimens. Because of this, the *F. megathyris* from all of the museum collections were pooled when used as comparisons to ***F. actiniophorum***. All of the *F. erosum* used for comparison were collected from the type locality, a single site off central California (Shimek & Moreno, 1996).

Table 2

Shell measurements taken of *Fissidentalium* ***actiniophorum*** (see Shimek & Moreno, 1996: fig 1 for a diagram of the measurements).

Basic Measurements		
LTot	=	Total Length
Larc	=	Length from the Posterior Aperture Forward to the Point of Maximum Distance to the Shell from a Chord Running Between the Dorsal Edges of Both Apertures.
ApW	=	Aperture Width
ApH	=	Aperture Height
arc	=	Maximum Distance to the Shell from a Chord Running between the Dorsal Edges of Both Apertures.
Derived Indices		
lnLTot	=	Natural Logarithm of (LTot)
lnLarc	=	Natural Logarithm of (Larc)
lnApW1	=	Natural Logarithm of ((ApW)+1)
lnApH1	=	Natural Logarithm of ((ApH)+1)
lnWmax1	=	Natural Logarithm of ((Wmax)+1)
Lindex	=	Natural Logarithm of ((LWmax)+1)/Natural Logarithm of (LTot)
whratio	=	(ApW)/(ApH)
Apratio	=	Natural Logarithm of ((ApW)+1)/Natural Logarithm of ((ApH)+1)
Ws	=	$\left(\frac{LTot}{\sqrt{(LTot - Larc)^2 + (arc)^2}}\right)^{1/\{atan[(arc)/lTot - Larc]\}}$

Soft-Body-Part Measurements

Soft-body-part proportions were measured from fixed material, which has been shown to provide reliable quantitative data (Voight, 1991; Shimek & Moreno, 1996). The methodology and measurements follow Shimek & Moreno (1996). Three basic soft-body-part components, the buccopedal or buccal region, the gut region, and the gonadal region, were measured. Some of these regions may be fixation artifacts; nevertheless, they provided consistent landmarks.

The buccal region was measured ventrally from the so-called periostracal groove on the outside of the mantle surrounding the ventral aperture to the groove separating this ventral component from the remaining soft body parts. The gut region was measured ventrally from the groove separating the gut area from the buccal region to the position of the anus. The gonadal region was measured ventrally from the anus to the mantle attachment ring on the mantle surrounding the dorsal aperture, and dorsally from the most posterior margin of the stomach to the mantle attachment ring surrounding the dorsal aperture.

Scanning Electron Microscopy

Whole radulae were cleaned of tissue residue in 5% sodium hypochlorite, dehydrated to 100% ethanol, and air dried. Shells were cleaned in alcohol and air dried. All specimens were mounted with silver paint on aluminum stubs, and gold-palladium plated. Micrographs were taken with an JEOL JSM-6100 Scanning Electron Microscope (SEM) at 15 KeV.

Statistics

The means and standard deviations of the measurements or the derived indices were computed. The whorl expansion rate is a logarithmic function, and calculations of this index are sensitive to small changes of shape. I used the mean of the natural logarithm of this and other logarithmically transformed or derived indices for comparative purposes. The mean of a logarithmically transformed numerical array is the median of the untransformed array. The median is a better indicator of the central tendency of these arrays than the mean as it is less sensitive to extreme values (Sokal & Rohlf, 1981). The mean of these factors are also given for comparative purposes.

The morphometric factors and indices were compared between and within populations by using standard statistical graphics software (Manugistics, 1992). The data were compared utilizing the distribution-free or non-parametric Kruskal-Wallis test to avoid having to making unwarranted assumptions about the distributions of the tested factors.

I used five basic measurements and eight calculated values to describe the shell (Table 2). Throughout this study, statistical significance was defined as $P = \alpha \leq 0.05$.

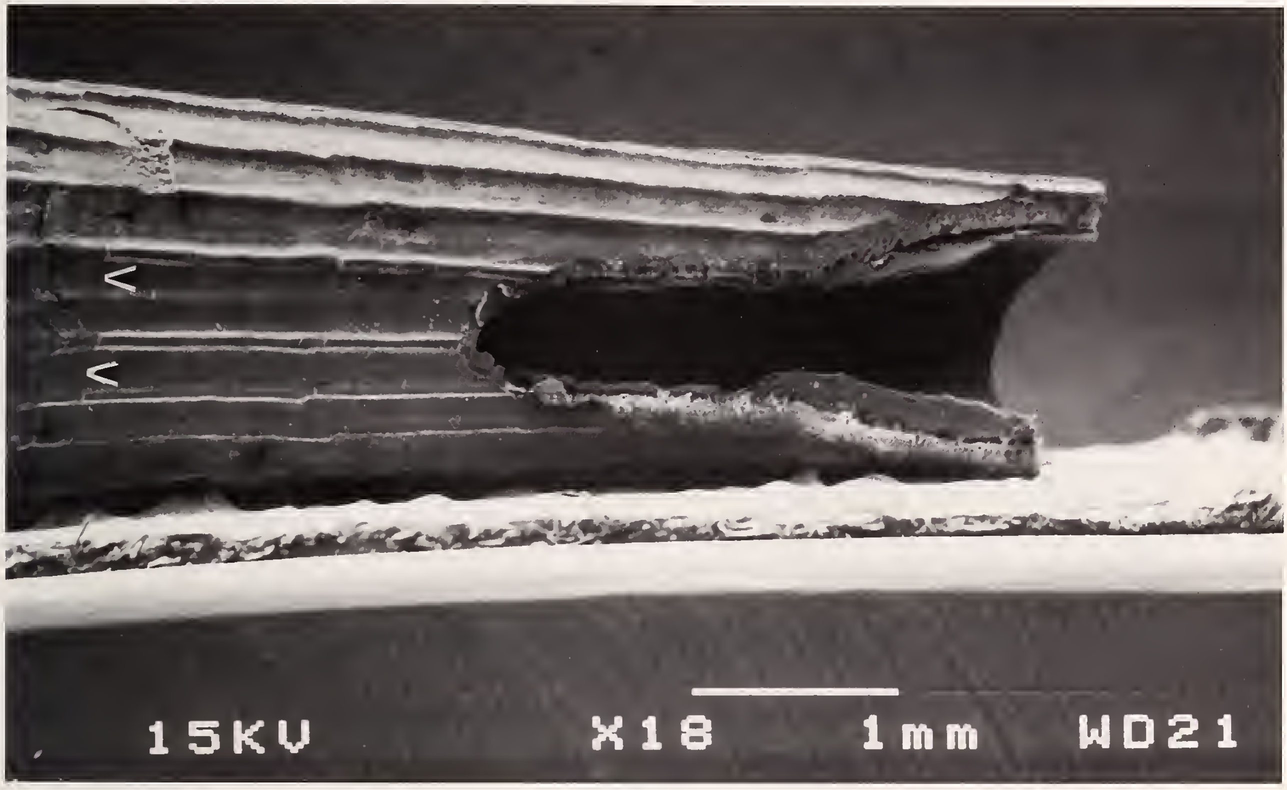

Figure 2

F. actiniophorum, Shimek, sp. nov. dorsal aperture, convex side, juvenile animal about 30 mm long. Note the slit or notch in the shell. This specimen had an anthozoan attached which has been removed. Arrowheads indicate areas of slight shell erosion at the edges of the attachment of the sea anemone.

SYSTEMATICS

Class Scaphopoda Bronn, 1862

Order Dentaliida Da Costa, 1776

Family Dentaliidae Gray, 1834

Fissidentalium P. Fischer, 1885

Type species: *Dentalium ergasticum* P. Fischer, 1882 (designation by monotypy).

Fissidentalium contains numerous large, generally robust, deep-water species. The shells often possess many pronounced longitudinal ribs or striae. *Fissidentalium* ***actiniophorum*** is an exception to these generalizations. It does not have a particularly robust shell, and the longitudinal striae, while present, are faint compared to most *Fissidentalium*. The generic name refers to the presence of a narrow posterior (on the convex side) slit proceeding ventrally from the dorsal aperture (Emerson, 1962; Palmer, 1974b; Steiner, 1992). This slit is found in many *Fissidentalium* species, including *F.* ***actiniophorum*** (Figure 2), but is lacking in a few, notably *F. megathyris*. *Fissidentalium* is easily recognized and widespread throughout the deep waters of the Pacific (Pilsbry & Sharp, 1897); however, most of the species have been described on the basis of limited collections and are relatively similar in gross morphology (Pilsbry & Sharp, 1897; Palmer, 1974a).

Fissidentalium ***actiniophorum*** Shimek, sp. nov.

Type material: The holotype and two paratypes are illustrated (Figure 3).

Holotype: LACM no. 2792.

Paratypes: LACM no. 2793 (Paratype A in Figure 3); USNM no. 886326 (Paratype B in Figure 3); LACM no. 2809 (6 specimens); LACM no. 2810 (4 specimens); LACM no. 2811 (2 specimens); BMNH no. 1996120 (1 specimen with sea anemone); BMNH no. 1996121 (2 specimens; collected with sea anemones, anemones subsequently removed).

Type locality: All type specimens came from samples collected at station M of the Pulse Project conducted by

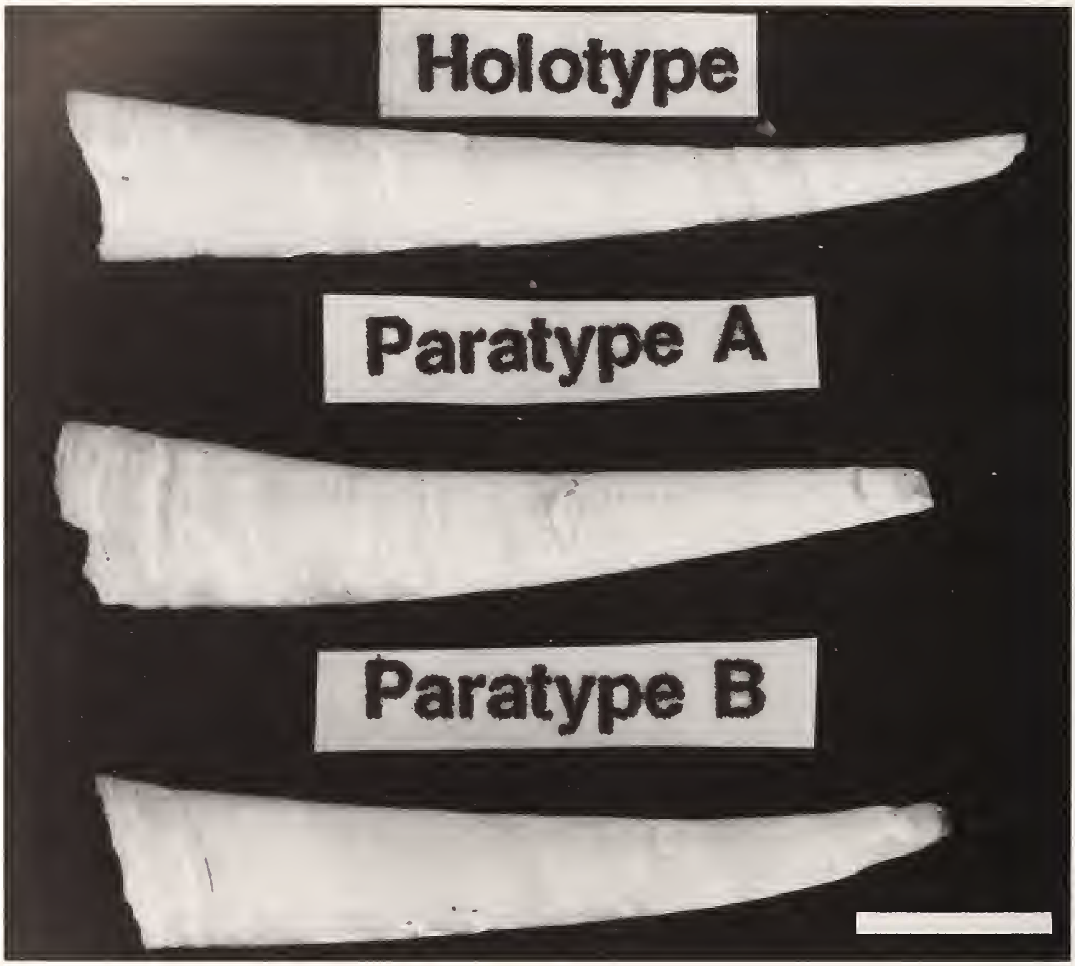

Figure 3

Type specimens; Holotype is LACM # 2792. Paratype A is LACM # 2793. Paratype B is USNM # 886326. Note faint longitudinal striae.

Dr. Ken Smith, Scripps Institution of Oceanography at depths varying from 4100 m to 4134 m.

Holotype collection data: Sta. 1809 M, Date: 4 November 1993, 34°44′N, 123°12′W.

Paratype collection data: LACM no. 2793, USNM no. 886326. Sta. 1820 M, Date: 7 November 1993, 34°42′N, 123°08′W. LACM no. 2809—Sta. 1625 M, Date: 24 February 1993, 34°45′N, 123°02′W. LACM no. 2810—Sta. 1809 M, Date: 4 November 1993, 34°44′N, 123°12′W. LACM no. 2811—Sta. 1906 M, Date: 5 February 1993, 34°41′N, 123°05′W. BMNE no 1996120—Sta. 2017 M, Date: 17 June 1994, 34°39′N, 122°58′W, BMNH no. 1996121—Sta. 1916 M, Date: 10 February 1994, 34°41′N, 123°11′W.

All other *F. actiniophorum* specimens also came from this station. The holotype had no anthozoan attached, but had the residue of attachment present. Some of the paratypes initially had anthozoans attached. Many anthozoans were not removed to facilitate the description of the anemone. If the anthozoans were not removed, then measurements of arc could not be taken and the derived indices utilizing that factor could not be calculated. The shells were cleaned in a solution of 2.5% sodium hypochlorite prior to measurement and photography.

Material examined: I examined 133 live-collected and 22 dead shell specimens of *F. **actiniophorum.*** Shells from dead specimens were measured only if they appeared to be intact without any damage. No dead shells carried an anthozoan. Ninety of the live-collected specimens carried an anemone; forty-three did not. Additional collections of *F. megathyris* and *F. erosum* specimens, including the type material, were examined for the comparative purposes (Tables 3, 4).

Table 3

Summary statistics of each of the meristic factors for *Fissidentalium megathyris*, *F. erosum*, and *F.* ***actiniophorum***. The number of specimens measured varied due to the condition of the shell or soft part, and the presence of anemones.

	Fissidentalium		
	megathyris	*erosum*	***actiniophorum***
LTot			
Sample size	76	14	153
Average ± 1 SD	78.06 ± 12.64	69.20 ± 5.24	47.78 ± 8.30
Median	80.58	69.08	48.05
Minimum	16.27	62.19	19.19
Maximum	102.19	77.77	91.72
Range	85.92	15.58	72.53
Larc			
Sample size	76	14	94
Average ± 1 SD	30.87 ± 5.78	31.67 ± 4.36	21.30 ± 5.17
Median	31.00	31.50	21.38
Minimum	7.95	25.09	10.10
Maximum	42.26	39.09	31.76
Range	34.31	14.00	21.66
ApW			
Sample size	76	14	155
Average ± 1 SD	13.54 ± 2.71	11.89 ± 0.56	8.06 ± 1.09
Median	13.84	11.82	8.20
Minimum	2.29	11.16	4.34
Maximum	18.04	13.12	10.84
Range	15.75	1.96	6.50
ApH			
Sample size	76	14	155
Average ± 1 SD	12.68 ± 2.41	11.74 ± 0.55	7.80 ± 1.06
Median	12.76	11.67	7.94
Minimum	2.00	11.04	4.32
Maximum	16.56	12.70	10.00
Range	14.56	1.66	5.68
arc			
Sample size	76	14	94
Average ± 1 SD	5.34 ± 2.25	4.43 ± 1.22	2.18 ± 0.75
Median	5.06	4.32	2.15
Minimum	1.49	2.46	0.72
Maximum	13.81	6.40	3.93
Range	12.32	3.94	3.21
lnLTot			
Sample size	76	14	153
Average ± 1 SD	4.34 ± 0.24	4.23 ± 0.08	3.85 ± 0.188
Median	4.39	4.24	3.87
Minimum	2.79	4.13	2.95
Maximum	4.63	4.35	4.52
Range	1.84	0.22	1.56
lnLarc			
Sample size	76	14	94
Average ± 1 SD	3.41 ± 0.24	3.45 ± 0.14	3.03 ± 0.26
Median	3.43	3.45	3.06
Minimum	2.07	3.22	2.31
Maximum	3.74	3.67	3.46
Range	1.67	0.44	1.15
lnApW1			
Sample size	76	14	155
Average ± 1 SD	2.65 ± 0.25	2.56 ± 0.04	2.20 ± 0.13
Median	2.70	2.55	2.22
Minimum	1.19	2.50	1.68

Table 3

Continued.

	Fissidentalium		
	megathyris	*erosum*	***actiniophorum***
Maximum	2.95	2.65	2.47
Range	1.76	0.15	0.80
lnApH1			
Sample size	76	14	155
Average ± 1 SD	2.59 ± 0.25	2.54 ± 0.04	2.17 ± 0.13
Median	2.62	2.54	2.19
Minimum	1.10	2.49	1.67
Maximum	2.87	2.62	2.40
Range	1.77	0.13	0.73
lnWmax1			
Sample size	76	14	155
Average ± 1 SD	2.59 ± 0.25	2.54 ± 0.04	2.17 ± 0.13
Median	2.62	2.54	2.19
Minimum	1.10	2.49	1.67
Maximum	2.87	2.62	2.40
Range	1.77	0.13	0.73
lnApH1			
Sample size	76	14	155
Average ± 1 SD	2.59 ± 0.25	2.54 ± 0.04	2.17 ± 0.13
Median	2.62	2.54	2.19
Minimum	1.10	2.49	1.67
Maximum	2.87	2.62	2.40
Range	1.77	0.13	0.73
Apratio			
Sample size	76	14	155
Average ± 1 SD	1.02 ± 0.02	1.00 ± 0.01	1.01 ± 0.02
Median	1.02	1.00	1.01
Minimum	0.99	0.99	0.97
Maximum	1.08	1.02	1.08
Range	0.09	0.03	0.11
Ws			
Sample size	76	14	94
Average ± 1 SD	2543 ± 17,915	615 ± 1064	$2.4 \times 10^{11} \pm 1.7 \times 10^{11}$
Median	99.89	233.40	961.06
Minimum	5.33	40.47	34.24
Maximum	156,440.00	3726.50	1.47×10^{11}
Range	156,434.67	3686.03	1.47 ± 10^{11}
lnWs			
Sample size	76	14	94
Average ± 1 SD	4.93 ± 1.77	5.43 ± 1.38	8.04 ± 4.10
Median	4.60	5.45	6.87
Minimum	1.67	3.70	3.53
Maximum	11.96	8.22	25.72
Range	10.29	4.52	22.18
Total viscera			
Sample size	22	19	126
Average ± 1 SD	37.59 ± 3.68	31.42 ± 4.79	25.44 ± 6.06
Median	36.55	31.70	24.81
Minimum	31.80	19.80	0.00
Maximum	49.10	38.90	40.92
Range	17.30	19.10	40.92
Buccal lobe			
Sample size	22	19	124
Average ± 1 SD	14.87 ± 1.77	14.32 ± 2.49	8.17 ± 2.09

Table 3

Continued.

	Fissidentalium		
	megathyris	*erosum*	***actiniophorum***
Median	15.30	14.70	8.36
Minimum	10.40	8.40	2.76
Maximum	17.40	18.30	14.11
Range	7.00	9.90	11.35
Gut lobe			
Sample size	22	19	124
Average ± 1 SD	8.13 ± 2.08	6.96 ± 1.71	5.70 ± 1.38
Median	8.45	7.30	5.68
Minimum	4.40	4.30	2.80
Maximum	12.20	9.80	10.92
Range	7.80	5.50	8.12
Gonad lobe—ventral			
Sample size	22	19	124
Average ± 1 SD	14.58 ± 3.10	10.14 ± 2.66	9.78 ± 3.36
Median	14.90	10.30	9.33
Minimum	9.20	6.30	3.74
Maximum	21.30	17.20	23.75
Range	12.10	10.90	20.01
Gonad lobe—dorsal			
Sample size	22	19	104
Average ± 1 SD	15.52 ± 2.40	12.23 ± 2.13	8.86 ± 2.44
Median	15.10	12.10	8.92
Minimum	10.40	8.80	2.81
Maximum	22.10	16.70	15.40
Range	11.70	7.90	12.59

Etymology: The epithet *actiniophorum* (from Greek: *aktinos* = "a ray or beam"; referring to the sea anemone or actinarian, and *phoreus* = "a bearer") refers to the association between the scaphopod and sea anemone that is borne on the functionally dorsal surface of most specimens. The name was suggested by Dr. Eugene Kozloff.

Diagnosis: A white *Fissidentalium* with numerous faint external longitudinal striae; shell surface dull with irregular annulations parallel to the ventral aperture; most live specimens have a sea anemone attached to the concave surface of the shell. Ventral aperture slightly wider than high. Young specimens with a posterior slit extending down the convex side of the shell from dorsal aperture (Figure 2). Gonadal length longer than either of the other two soft-body-part regions.

Detailed description: Specific measurements of the holotype and paratypes are given in Table 5. Unless otherwise noted, all measurements in the description are means ± one standard deviation of all *F. **actiniophorum*** specimens and were taken from Table 3.

Shell large, mean total shell length 47.8 ± 8 mm, evenly curved; shell length from dorsal aperture to point of maximum curvature 21.3 ± 5.2 mm; point of maximum arc posterior to, but near, the shell middle (Figure 3).

Ventral aperture slightly oblique to dorso-ventral axis; approximately circular, slightly wider than high; aperture width 8.1 ± 1.1 mm; aperture height 7.8 ± 1.1 mm.

Shell curvature slight; maximum curvature 2.2 ± 0.75 mm; whorl expansion rate $2.4 \times 10^{10} \pm 1.7 \times 10^{10}$.

Length of preserved, unrelaxed, soft-body-part mass 25.9 ± 5.2 mm; length of buccal region 8.2 ± 2.1 mm; gut region 5.7 ± 1.4 mm. Ventral gonadal region length 9.8 ± 3.4 mm; dorsal gonadal region length 8.9 ± 2.4 mm.

Radula (Figure 4) of "*Antalis* type" (Chistikov 1975), similar to *F. megathyris* and *F. erosum*; lateral teeth convex anteriorly, concave posteriorly bearing pointed forward projections where bent; marginal teeth with wavy contours and three curvatures; rachidian teeth concave dorsally, with transverse ridges, cross-section "S"-shaped allowing teeth to fit tightly together. Rachidian and lateral teeth movable on radular ribbon; marginal teeth immobile, imbedded in ribbon.

Shell, thin compared to *F. megathyris* and *F. erosum*, about 150 μm thick, with three layers; a thin outer aprismatic layer, 2–4 μm thick; a middle layer of vertically

Table 4

Results of pairwise tests between *F.* ***actiniophorum*** and each of *F. megathyris,* and *F. erosum* for the meristic factors. The test was the non-parametric Mann-Whitney U test of unpaired data. Tested taxon = Taxon tested against *F.* ***actiniophorum***; Z = Large sample test statistic; and *P* = probability that the tested taxon data and *F.* ***actiniophorum*** data could be drawn randomly from the same population. n = total number of values.

Variable	Tested taxon	Z	*P*	*n*
A. Shell measurements				
LTot	*megathyris*	−11.209	< 0.001	229
	erosum	−6.087	< 0.001	167
Larc	*megathyris*	−9.050	< 0.001	170
	erosum	−5.287	< 0.001	108
ApW	*megathyris*	−11.300	< 0.001	231
	erosum	−6.186	< 0.001	169
ApH	*megathyris*	−11.250	< 0.001	231
	erosum	−6.186	< 0.001	169
Arc	*megathyris*	−10.022	< 0.001	170
	erosum	−5.442	< 0.001	108
B. Derived shell measurements				
lnLTot	*megathyris*	−11.209	< 0.001	229
	erosum	−6.084	< 0.001	167
lnLarc	*megathyris*	−9.050	< 0.001	170
	erosum	−5.287	< 0.001	108
lnApW1	*megathyris*	−11.300	< 0.001	231
	erosum	−6.186	< 0.001	169
lnApH1	*megathyris*	−11.250	< 0.001	231
	erosum	−6.186	< 0.001	169
lnHmax1	*megathyris*	−11.250	< 0.001	231
	erosum	−6.186	< 0.001	169
Apratio	*megathyris*	−3.350	< 0.001	231
	erosum	2.690	0.007	169
whratio	*megathyris*	−4.160	< 0.001	231
	erosum	2.415	0.015	169
Ws	*megathyris*	6.969	< 0.001	170
	erosum	2.986	0.002	108
Total viscera	*megathyris*	−6.909	< 0.001	146
	erosum	−4.059	< 0.001	143
Buccal lobe	*megathyris*	−7.303	< 0.001	146
	erosum	−6.405	< 0.001	143
Gut lobe	*megathyris*	−4.669	< 0.001	146
	erosum	−3.018	0.002	143
Gonadal lobe (ventral)	*megathyris*	−5.388	< 0.001	146
	erosum	−0.723	0.470	143
Gonadal lobe (dorsal)	*megathyris*	−7.027	< 0.001	126
	erosum	−4.787	< 0.001	123
D. Derived soft part measurements				
Buccal lobe/total viscera	*megathyris*	−4.368	< 0.001	146
	erosum	−6.111	< 0.001	143
Gut lobe/total viscera	*megathyris*	0.528	0.598	146
	erosum	0.116	0.908	143
Gonadal lobe (ventral)/total viscera	*megathyris*	−0.555	0.579	146
	erosum	2.263	0.024	143
Gonadal lobe (dorsal)/total viscera	*megathyris*	−3.910	< 0.001	126
	erosum	−2.712	0.007	123

oriented prisms, about 30 μm thick; and an inner crossed-lamellar layer, about 120 μm thick (Figure 5).

Shell white, dull, not polished; numerous irregular annulations present; patchy eroded areas common. Shell apical end often missing, due to decollation (Reynolds, 1992), or predation (Shimek, 1990). A secondary shell extends from the dorsal aperture on many specimens (See Paratype B, Figure 3). Longitudinal striae visible with magnification

Table 5

Type specimen measurements. All measurements are in millimeters. Measurements and derivations are described in Shimek & Moreno, 1996. H = Holotype; P = Paratypes; NM = Not measured; ND = Not derived. LACM = Los Angeles County Natural History Museum, USNM = Natural History Museum of the United States, BMNH = British Museum of Natural History.

Category	H	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Museum	LACM	LACM	USNM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	LACM	BMNH	BMNH	BMNH
Lot number	2792	2793	886326	2809	2809	2809	2809	2809	2809	2810	2810	2810	2810	2811	2811	1996121	1996120	
Anthozoan present	NO	YES	YES	NO	YES	YES	NO	YES	NO	NO	YES	YES	YES	NO	YES	YES	YES	YES
A. Shell measurements																		
Total length	50.55	46.10	48.05	47.34	48.68	51.4	51.8	55.81	56.31	31.71	56.51	58.97	61.21	38.71	43.06	40.46	51.01	44.00
Aperture height	8.61	8.46	8.16	8.66	7.50	8.16	7.88	7.82	9.05	5.58	8.97	8.34	9.81	6.74	7.00	5.82	8.37	7.96
Aperture width	8.48	9.06	8.54	8.86	7.64	7.82	7.90	8.12	9.46	5.59	8.87	8.57	9.65	7.06	7.59	6.94	8.76	7.54
arc	2.00	2.86	1.56	2.06	NM	NM	2.74	NM	3.74	NM	NM	NM	NM	NM	NM	NM	NM	NM
Length to Max. arc	28.35	28.00	25.33	21.26	NM	NM	20.14	NM	26.10	NM	NM	NM	NM	NM	NM	NM	NM	NM
B. Derived shell measurements																		
lnLTot	3.92	3.83	3.87	3.86	3.88	3.94	3.95	4.02	4.03	3.46	4.03	4.10	4.11	3.66	3.76	3.70	3.93	3.78
lnLarc	3.34	3.33	3.23	3.06	ND	ND	3.00	ND	3.26	ND	ND	ND	ND	ND	ND	ND	ND	ND
lnApW1	2.25	2.31	2.26	2.29	2.16	2.18	2.19	2.21	2.35	1.88	2.29	2.26	2.37	2.09	2.15	2.07	2.28	2.14
lnApH1	2.26	2.25	2.21	2.27	2.14	2.21	2.18	2.18	2.31	1.89	2.30	2.23	2.38	2.05	2.08	1.92	2.24	2.19
Hindex	0.99	1.03	1.02	1.01	1.01	0.98	1.00	1.02	1.02	1.00	1.00	1.01	0.99	1.02	1.03	1.08	1.02	0.98
hindex	0.98	1.07	1.05	1.02	1.02	0.96	1.00	1.02	1.02	1.00	1.00	1.01	0.99	1.02	1.03	1.08	1.02	0.98
Ws	9077	332	40676	1852	ND	ND	287	ND	147	x	ND	ND	ND	ND	ND	ND	ND	ND
lnWs	9.11	5.80	10.61	7.52	ND	ND	5.66	ND	4.99	x	ND	ND	ND	ND	ND	ND	ND	ND
C. Soft body part length measurements																		
Total visceral length	34.38	26.97	24.76	24.16	23.85	NM	NM	25.76	26.14	23.49	40.92	39.22	35.5	NM	23.12	24.60	31.96	32.52
Buccal lobe	10.66	8.70	6.86	9.07	6.86	NM	NM	6.06	11.41	6.52	6.42	7.77	8.74	NM	5.19	4.48	9.52	7.56
Gut lobe	4.86	4.84	6.06	6.68	5.71	NM	NM	5.97	5.02	4.44	8.36	5.46	4.56	NM	4.36	4.94	5.99	6.34
Gonad lobe—vent.	8.86	6.50	6.38	8.41	11.28	NM	NM	13.73	9.71	6.21	15.59	13.45	10.74	NM	7.21	7.54	8.49	9.28
Gonad lobe—dor.	10.00	6.93	5.46	9.62	11.1	NM	NM	12.78	10.64	6.32	10.55	12.54	11.46	NM	6.36	7.64	7.96	9.34
Gender	M	F	M	F	M			M	F	I	F	F	M		?	M	M	F

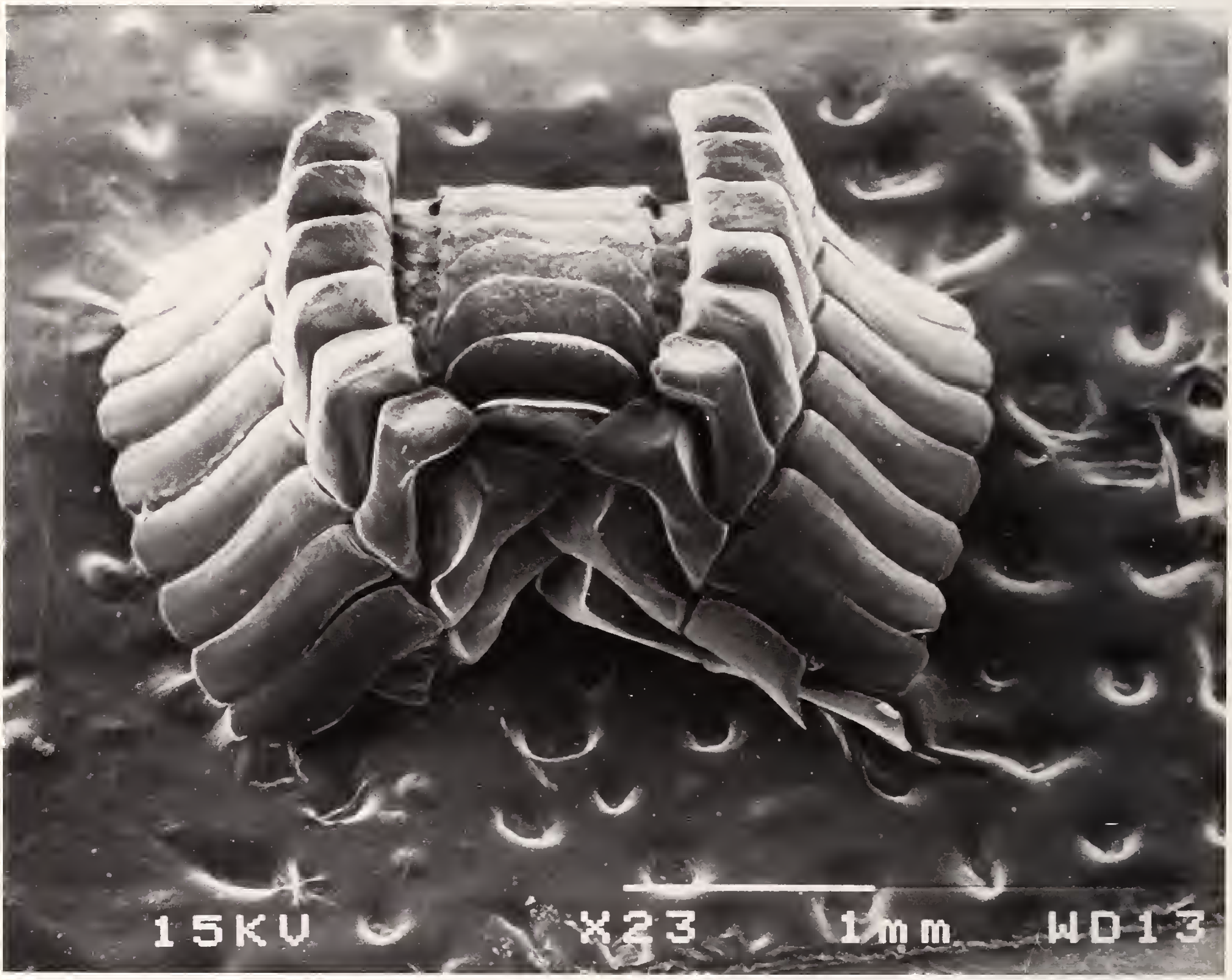

Figure 4

Radula of *F. actiniophorum*; Shimek, sp. nov. whole mount of the radula is shown from the posterior, the action plane to the top.

found near the dorsal aperture. Longitudinal striae on the rest of the uneroded shell faint, but generally visible without magnification and clearly visible with magnification. Faint surface marks at edges of the sea anemone attachment zone observed on some animals (Figure 2).

Remarks: The gender of 90 specimens was determined when the animals were measured. Based on gonadal examination, most of the *F. actiniophorum* examined were adults, containing either masses of sperm or ova. Only 10 *F. actiniophorum* juveniles or small animals of indeterminate sex were collected, probably due to the sampling method. Where gender was determined, the sex ratio was approximately 1:1; thirty-eight females and 42 males were collected. There were slight, non-significant differences in gender with regard to the presence of the anemones on the shell. Of the 90 animals whose gender was determined, 56 had anemones on the shell (31 ♂, 25 ♀), 24 were without anemones (11 ♂, 13 ♀).

There may be a general correlation between scaphopod gonadal length and season (G. Steiner, personal communication). Preliminary statistical analysis indicated that such a correlation may occur with these samples; however, given the small individual sample sizes, variations in the size of the individuals and gonads, and the pooling necessary for adequate analysis, the variance in the data was too extreme to confirm this (Shimek, unpublished data).

Whether the symbiosis of anthozoan and scaphopod is mutually beneficial is unclear. Obviously the anthozoan gains a substrate to attach to in an area that may be bereft of suitable attachment sites. Any costs or benefits to the scaphopod of this association are not immediately apparent; however, there does appear to be some slight superficial shell erosion due to attachment of the anemone on

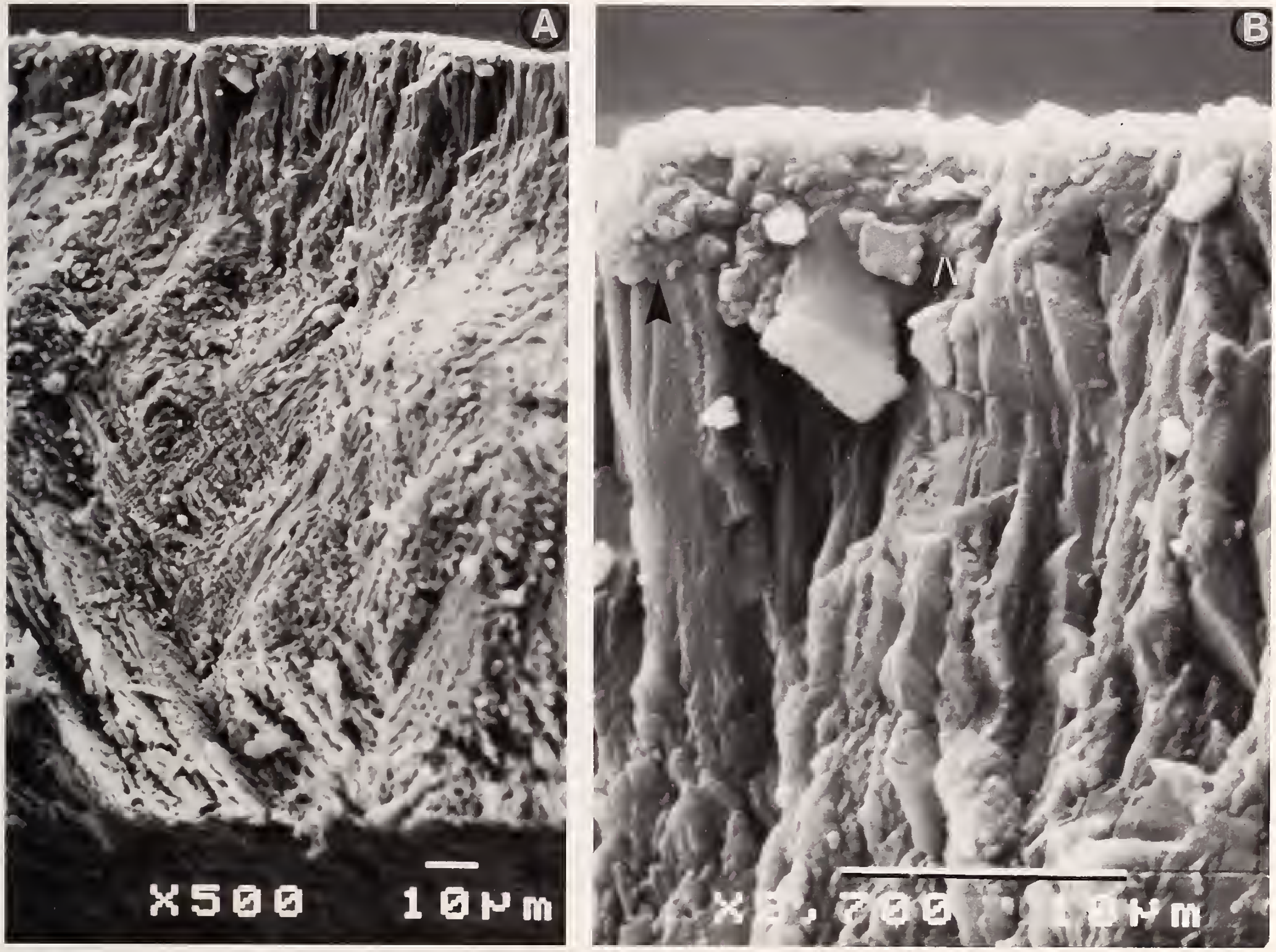

Figure 5

Cross section of a fractured *F. **actiniophorum*** Shimek, sp. nov. shell showing microstructure. The outer surface of the shell is at the top. A. The entire thickness of the shell is visible. B. Higher magnification of the area below the vertical white bars above the shell in Figure 5A. Note the thin amorphous outer layer (indicated above the arrowheads in Figure 5B) on top of the layer of vertical prisms, and the thicker inner crossed-lamellar structure (Figure 5A).

some specimens (Figure 2). Additionally, it seems unlikely that the scaphopod could move through sediments as easily with the anthozoan attached as it might be able to without the anemone. Rapid movement through sediments, however, is more a feature a gadilid scaphopods rather than dentaliids (Shimek, 1990) and may be relatively unimportant to this species.

The only other large scaphopods found geographically near *F. **actiniophorum*** are *F. erosum* and *F. megathyris,* which are found in shallower water, generally from 1000 m to 2500 m for *F. megathyris,* and around 3300 m for *F. erosum* (Nybakken et al., 1992; Shimek & Moreno, 1996). The latter two species are almost indistinguishable from each other in most regards as to shell shape, but are significantly larger and decidedly more robust than *F. **actiniophorum*** (Figure 6). *Fissidentalium* ***actiniophorum*** was visually distinct when compared to either *F. erosum* or *F. megathyris.* It is smaller than either, and lacks the pronounced ribbing of *F. megathyris* and the extensive surface erosion of *F. erosum.* The basic color differs as well; *F. **actiniophorum*** is a milky white, while the other two species are more of an ivory color.

On the basis of shell and gross soft-body-part morphology, *F. **actiniophorum*** was clearly distinct and statistically significantly different from *F. erosum* and *F. megathyris* (Table 4). The significant differences between *F. **actiniophorum*** and these two morphologies were related to both relative and proportional differences in size, and were reflected in both external and some internal meristic factors (Table 3, 4). Because of all of these differences, I concluded that *Fissidentalium* ***actiniophorum*** was a distinct species.

Figure 6

Left lateral views of the shells of *F.* ***actiniophorum*** Shimek, sp. nov. (top) and *F. megathyris* (bottom). Scale bar = 5 mm.

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